Procedure for constructing an E-VPG using the method described in Claim 9

(This is the exact procedure used for making E-VPGs that have been supplied to several telecom companies.)

To create an E-VPG for a given wavelength, λ, one merely selects some integer values for s and p, with the restriction that s > p > 0. For the simplest case, one would select p = 1 and s = 2. This allows 2θ to be calculated from the equation for 2θ in claim 9. Since the bulk refractive index, n, of the volume phase medium is generally known, the grating period, d, can then be calculated for any selected value of the internal angle of incidence, α. In the most common case, $\alpha = \beta$. It then follows, for this case, that $\alpha = \theta$ and, from the equation in Claim 9,

$$d = \frac{\lambda}{2n\sin\theta} = \frac{\lambda}{2n\sin\alpha}.$$

Methods for creating the calculated grating period, d, in the volume phase medium are well known in the art. Interferometric methods are the most common.

For a given medium thickness, T, the value for the modulation index, Δn, is then determined from the equation for Δn in claim 9, where all the parameters are now known. The procedure for obtaining a given value of Δn in the exposure and processing of dichromated gelatin is well known in the art and may be found in a number of references, including the following two references: D. Meyerhofer, RCA Review Vol. 33, p. 110 (1972); M. Chang, Applied Optics, Vol. 10, p. 2550 (1971).

Response to Rejection in Detailed Action item 2 - Failure to comply with 35 U.S.C. 112, first paragraph

Claims have been re-written such that they now satisfy 35 U.S.C. 112, first paragraph. New Claim 9 now provides an enabling recipe for constructing an Enhanced Volume Phase Grating of applicant's invention.

Response to Rejection in Detailed Action item 3 - Failure to comply with 35 U.S.C. 112, first paragraph

Methods for making AR coatings to meet a specific requirement are well known in the art. The novelty in applicant's invention is the specific requirement that the S loss be slightly greater than P loss at the nominal free-space wavelength of the telecom band.

Anti-reflection coatings are supplied by a variety of vendors. In practice, the customer specifies the desired S and P reflectances at a particular wavelength and a particular

angle of incidence for a particular medium. The vendor then applies multiple layers of thin dielectric films of different refractive indexes to the medium to give the desired result. Such coating technologies are well known in the art and are not the novel element of the applicant's invention. What is novel in the applicant's invention is the non-obvious decision to make the overall S-polarization loss slightly greater than the overall P-polarization loss at the nominal wavelength of the telecom band. Since the roll-off of diffraction efficiency at the ends of the wavelength band is greater for P-polarization in the present invention, the net result is that the worst-case polarization dependent loss is reduced (see Fig. 14 of applicant's application).

Response to Rejection in Detailed Action item 5 - Failure to comply with 35 U.S.C. 112, second paragraph

Claims have been re-written such that they now satisfy 35 U.S.C. 112, second paragraph. New Claim 9 now provides a detailed description of the physical structure of the invention.

Response to Rejection in Detailed Action item 6 - Failure to comply with 35 U.S.C. 112, second paragraph

Claims have been re-written such that they now satisfy 35 U.S.C. 112, second paragraph. New Claim 9 now clearly identifies the invention as an Enhanced Volume Phase Grating - a significant advancement in the art of Volume Phase Gratings.

Clarification in response to the fourth paragraph of Detailed Action item 6.

Diffraction efficiency is defined for the volume phase medium.

The diffraction efficiency is the ratio of the power in the diffracted beam to the power in the incident beam, ignoring Fresnel reflection losses. That is, it is the fundamental diffraction efficiency of the diffracting medium (the volume phase medium). Additional losses are encountered due to Fresnel reflection losses at the air/glass interfaces (assuming, for purposes of discussion, glass for the transparent cover means and rigid support means and assuming that Fresnel reflection losses are negligible at the glass/volume-phase-medium interface due to the use of an index-matching adhesive).

In some cases, one will want these Fresnel reflection losses to be minimized and equal for both polarizations - S and P. However, when the grating is to be used as a WDM multiplexing device, there may be an advantage in having the overall S-reflection losses slightly greater than the overall P-reflection losses at the nominal wavelength of the telecom band in order to minimize the worst case polarization dependent loss. That is what is shown in Fig. 14 of applicant's application.

Response to Rejection of Detailed Acti n item 8 - Prior Art: Jannson et.al. and Kat , et. al.

The rejections of Claims 1-4 and 5-8 on Jannson are overcome. Jannson does not teach equalization of S and P diffraction efficiencies for high diffraction efficiency, high dispersion gratings.

Jannson discusses Bragg volume gratings, which is not novel in his patent nor is it novel in applicant's invention. However, he does not teach that volume transmission holographic gratings, in general, have equal diffraction efficiencies for both S and P polarizations. What he merely states, without proof or reference, (in column 11, lines 34 to 44) is that in volume holographic gratings both polarizations "have roughly the same diffraction efficiency". By itself, this statement is false, unless a very loose definition of "roughly" is assumed. It is not clear whether Jannson is talking about reflection volume holographic gratings or transmission volume holographic gratings in this section. However, his statement is, in general, false in either case.

It is well known that in a reflection volume holographic grating, the S and P diffraction efficiencies approach equality as the thickness gets very large and the index modulation gets very large. In practice, equality is never reached and in most cases the difference is fairly large. So Jannson's statement is always false for reflection volume holographic gratings.

For transmission volume holographic gratings, which are the subject of applicant's invention, his statement is again, in general, false. His statement is true only if either the dispersion of the grating is low or the S and P diffraction efficiencies of the grating are low, which can be seen by examining Figures 4 and 5 of applicant's application. In Fig. 5, the dispersion is low and in Fig. 4, the S and P diffraction efficiencies are low at the value of index modulation for which the two diffraction efficiencies are equal. Such gratings would have little value in WDM applications.

Figures 3, 4 and 5 of applicant's application are completely general and apply to all transmission volume phase gratings, including those of Jannson. Fig. 4 shows that Jannson's claim that the S and P polarization components "have roughly the same diffraction efficiency" is completely false for high dispersion volume phase gratings.

Figures 3, 4 and 5 of applicant's application are theoretical curves for general volume holographic gratings showing the variation of the S and P diffraction efficiencies as functions of the index modulation, Δn, for a fixed medium thickness, T. These graphs were created using the well-known Kogelnik theory. The only differences in the three graphs are the angles of incidence and diffraction. In Fig. 4, the angles are large and in Fig. 5 the angles are small. Once the angles are selected and the thickness of the

medium is established, the only thing that affects the S and P diffraction efficiencies is the index modulation. All volume transmission holographic gratings will have characteristics similar to those shown in Figures 3, 4 and 5, including the volume transmission holographic gratings of Jannson. Once the thickness and index modulation of a volume transmission holographic grating are fixed, the S and P diffraction efficiencies will be established from the graph corresponding to the selected angles.

Fig. 5 of applicant's application shows the variations of the S and P diffraction efficiencies as functions of the index modulation for a conventional volume phase grating in which the dispersion is low. In this case, equality of diffraction efficiency for the two polarizations occurs at the point where the two curves intersect ($\Delta n = 0.055$). The diffraction efficiencies are relatively high but the dispersion is low, as indicated by the relatively small amount of lag between the two curves (The amount of lag is determined by the angles of incidence and diffraction. Small angles result in small lag but small angles also result in low dispersion.). In contrast, applicant's enhanced volume phase gratings are high dispersion gratings. (See Fig. 9 in applicant's application and note the large amount of lag between the two curves.)

Fig. 4 of applicant's application shows the variations of the S and P diffraction efficiencies as functions of the index modulation for a conventional volume phase grating in which the dispersion is high (as indicated by the large amount of lag between the two curves). Once again, equality of diffraction efficiency for the two polarizations occurs at the point where the two curves intersect ($\Delta n = 0.065$). While the dispersion will be high for this case, the diffraction efficiencies at the point of equality will be very low (30%). In contrast, applicant's enhanced volume phase gratings provide high diffraction efficiencies for both polarizations at the point of equality. (See Fig. 9 in applicant's application and note that both diffraction efficiencies are maximum at the point of coincidence, where $\Delta n = 0.21$ and Es = Ep).

Novelty of applicant's invention over Jannson is the combination of high dispersion plus equal and maximum S and P diffraction efficiencies plus low PDL across a full telecom band.

What is novel in applicant's invention, and not discussed in Jannson, is a <u>high dispersion</u> volume holographic grating in which the diffraction efficiencies for the S and P polarizations are simultaneously <u>equal and maximized</u>. Fig 9 of applicant's application, shows that the equality point, where Es = Ep, occurs at the second peak of the Es curve and the first peak of the Ep curve so that the diffraction efficiencies for both polarizations are simultaneously maximized. <u>This is the major novelty in applicant's invention.</u> The large lag between the two curves in Fig. 9 also indicates that the angles of incidence and diffraction are fairly large for this grating design so that this grating will also have very high dispersion.

Furthermore, since the two curves coincide at a maximum value of diffraction efficiency, the diffraction efficiency for both polarizations will decrease slowly as wavelength either increases or decreases to either side of the nominal wavelength of the telecom band for which the grating is designed (See Fig. 10 in applicant's application). The grating will then have both low insertion loss and low PDL across the full width of the telecom band. In contrast, if an Es-Ep intersection point for a conventional volume phase grating is selected to equalize the diffraction efficiencies, the variation of diffraction efficiency with wavelength will be much greater, and the rate of change will be significantly different for the two polarizations. Therefore, the insertion loss and PDL for such a grating will both be much larger across the full width of the telecom band.

In summary, Jannson does not disclose, teach or suggest a volume phase grating having the highly desirable combination of (a) very high dispersion, (b) equal and maximized diffraction efficiencies for S and P polarization, (c) high S and P diffraction efficiencies across the full width of a telecom band and (d) very low PDL across the full width of a telecom band. In contrast, applicant's application teaches all of this and provides a recipe for making an enhanced volume phase grating, which has all of these desirable attributes.

E-VPG is a major advancement of the art, as confirmed by several telecom companies.

The enhanced volume phase grating of the applicant's invention has high dispersion, equal diffraction efficiencies for both polarizations, maximum diffraction efficiency for both polarizations, slow variation of diffraction efficiency with wavelength and a small difference between the two diffraction efficiencies across a wide wavelength range, all of which makes it a novel and desirable grating for telecom applications and a significant contribution to the advancement of the art. Several telecom companies have tested applicant's enhanced volume phase gratings and have concluded that they are a significant advancement of the art and no other grating can match it's performance.

It is significant to note that the Jannson patent was issued nearly 11 years ago, yet no volume phase grating comparable to applicant's E-VPG has ever been developed using the technology described in Jannson. If Jannson taught all that is taught in applicant's application, it is highly likely that gratings similar to the E-VPG and based on the Jannson patent would have been manufactured and would be in widespread use in the telecom industry today since they would have significant advantages over all other commercially available gratings. The fact that E-VPG type gratings based on the Jannson patent are not commercially available implies, rather strongly, that Jannson does not teach what is taught in the applicant's application.

With regard to the last paragraph in item 8 of the Office Action, applicant's invention provides a means to minimize the maximum difference between the diffraction efficiencies of the S- and P- polarization light components across the full width of a telecom pass band. Jannson does not teach this and, as noted above, he does not even teach minimizing the difference at the nominal wavelength of the telecom band unless one uses a very low dispersion grating. Even then, Jannson does not teach how to do this. He merely makes a statement that, in general, is false.

The dependent claims are a fortiori patentable over Kato

New dependent claims 10 to 16 incorporate all the subject matter of new independent claim 9, which applicant now submits is patentable over Jannson, and they also add additional subject matter, which makes them a fortiori patentable over Kato, which does not teach the novel art of applicant's Claim 9.

Kato teaches the use of a transparent support medium, a transparent cover medium, a transparent adhesive sealing layer and an anti-reflection coating. While, by themselves these features would not be novel in applicant's invention, they become a fortiori patentable over Kato when incorporating the patentable novelty of Claim 9.

Similarly, while Kato teaches an arrangement having a reflecting film placed at exterior surfaces of a convex lens, serving as a cover plate, the use of a reflecting element in the applicant's invention is a fortiori patentable over Kato when incorporating the patentable novelty of Claim 9.

Response to Detailed Action item 9 - Prior Art: Albert, et. al.

Different definition of the term "polarization sensitivity"

In the Albert patent, the term "polarization sensitivity" is defined differently than it is in applicant's application. In Albert, "polarization sensitivity" refers to the difference in the velocities of propagation for the two orthogonal polarizations. This is a result of the birefringence of the waveguide. Birefringence is essentially two refractive indexes, one for each of the two orthogonal polarization directions. What Albert teaches is a means for "controlling the amount of birefringence present in a planar waveguide" (See column 5, line 10). He does not teach anything about diffraction efficiencies.

Applicant's invention provides a means for reducing the "polarization sensitivity" of a volume phase grating, where now the term "polarization sensitivity" refers to the difference in the diffraction efficiencies for the two orthogonal polarizations. This is unrelated to birefringence or the velocities of propagation of the two orthogonal polarizations as discussed in Albert.

Response t Detailed Action item 9 - Prior Art: Okumura, et. al.

The dependent claims are a fortiori patentable over Okumura

Okumura discloses an anti-reflection coating that has different reflectances for the S and P polarized light but he does not describe a means for establishing the difference between the two reflectances such that the maximum overall difference between the diffracted light of the two polarizations across the full width of a telecom band is minimized. Furthermore, even if Okumura teaches this difference between the S and P reflectances, the use of this concept in the applicant's invention is a fortiori patentable over Okumura when incorporating the patentable novelty of Claim 9. Okumura does not teach the art of applicant's Claim 9.

Applicant further submits that this result is not obvious to one skilled in the art. If it were obvious to one skilled in the art it would have already been used by manufacturers of conventional volume phase gratings, but it has not. The difference in the roll-off of diffraction efficiency for the two orthogonal polarizations is much greater for conventional volume phase gratings (see Fig. 8 of applicant's application) and the improvement obtained by the applicant's invention would be even more dramatic for these gratings. The worst- case polarization dependent loss could be lowered from 30% to 15%. Since the novel concept in applicant's Claims 15 and 16 has not heretofore been used for conventional volume phase gratings, even though the improvements would be quite dramatic, it must not be obvious to one skilled in the art.

Non-obviousness validated through commercial success

Several large telecom companies have tested samples of the Enhanced Volume Phase Grating and found their performance to exceed that of all other commercially available diffraction gratings in WDM applications. This implies that the advancements resulting from applicant's invention are both novel and non-obvious. Otherwise, since they offer significant advantages in WDM applications, such gratings would have been produced prior to applicant's introducing them.

Enhanced Volume Phase Gratings are now being offered commercially through a company co-founded by the applicant. Information about the company and the gratings can be found at www.wasatchphotonics.com. Several pages from this web site are included in applicant's response as Exhibits A-1 through A-5. A photograph of a typical enhanced volume phase grating is also included as Exhibit B.

Conclusion

For all the reasons given above, applicant respectfully submits that the claims now comply with 35 U.S.C. 112 and that the claims are of patentable merit under 35 U.S.C. 103(a) because of the specific novelty of creating a high-dispersion volume phase grating with equal and maximum S and P diffraction efficiencies and low PDL across the full width of a telecom band. Accordingly, applicant submits that this application is now in full condition for allowance.

If the examiner agrees that the subject matter of this application is clearly patentable but does not feel that the present claims are technically adequate, applicant respectfully requests that the examiner write acceptable claims pursuant to MPEP 707.07(j) in order that the applicant can place this application in allowable condition as soon as possible and without the need for further proceedings.

Respectfully submitted,

Dated: January 30, 2002

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Exhibit A-1

The Ultimate Gratings for DWDM and OSA

Wasatch Photonics specializes in high performance diffraction gratings and holographic optics for Telecom, Fiberoptic, Laser, Raman, and Optical Spectrum Analysis Applications. Our cutting-edge DWDM products combine ALL of the best features into ONE grating:

Telecom-Grade Dickson™ Gratings and Grisms

- High Dispersion
- Extremely High Diffraction Efficiency (>95%)
- Extremely Low PDL (<0.2dB)
- Flat Response Across C, S, or L Bands
- Low Stray Light
- **Used in 80 Channel, 50 GHz Multiplexers**
- **Very Small Footprint**
- **Hermetically-Sealed, Robust Packaging**
- **Long Life**
- **Affordable**

Our entrepreneurial founders are optical innovators with over 100 years of industry experience and have written over 50 patents. Over the years, we have made such well-known products as:

- **Supermarket Bar Code Scanner Optics**
- **Spectrometers**
- **Fingerprint Identification Devices**
- **3-D Anti-Counterfeiting Labels**
- **F/1 Collection Optics for Free Space Interconnects at 2.2 GHz**

We provide a high level of customer service. Additionally, we offer consulting, design, prototype, product integration, and quantity production at competitive prices. For sales info contact 925-274-1500, email us, or send us a completed Customer Grating Worksheet.

webmaster@wasatchphotonics.com

Exhibit A-2

The Ultimate Gratings for DWDM and OSA

Products

Wasatch Photonics combines its patent pending technology with trade secrets to make Enhanced-Volume Phase Gratings. These all-in-one, high performance gratings are ideal for many applications including Multiplexing, F/1 collection optics for free space interconnects at 2.2 GHz, Laser Tuning, and Optical Spectrum Analysis.

DWDM-Quality Gratings:
We make patent pending Dickson™ gratings for next generation systems and also drop-in replacement gratings for current generation systems. Each of our DWDM gratings combines ***ALL*** of these features into ***ONE*** grating:

- High Dispersion
- Extremely High Efficiency (>95%)
- Extremely Low PDL (≤0.2dB)
- Flat Response Across C, S, or L Bands

Grating Properties:

- Additional Technical Information On Dickson™ Gratings
- Enhanced - Volume Phase Gratings Recorded In Dichromated Gelatin (DCG)
- DCG Is Sealed In Between Glass Substrates
- Rugged, Scratch Resistant, & Easily Handled
- High Thermal Stability

Capabilities:

- Custom Groove Frequencies
- Custom Wavelengths
- Prism & Mirror Configurations
- Various Substrates (e.g. Fused Silica)
- AR Coating
- Aluminum & Gold Reflection Coating

Let us make products for your specific needs. Please review our Grating FAQs, fill out our Customer Grating Worksheet, or contact us .

Exhibit A-3

The Ultimate Gratings for DWDM and OSA

Grating FAQs

1. What type of gratings does Wasatch Photonics manufacture?
2. What information is available on your gelatin recording medium and is it stable over time?
3. What is a Dickson™ grating and why is it different from other gratings?
4. What kind of performance characteristics can be expected from a Dickson™ grating?
5. Can gratings with different dispersion angles be made?
6. Over what wavelengths can your gratings operate?
7. What physical sizes can be made?
8. What wavefront uniformity/distortion can be expected?
9. What environmental tests have been performed on your gratings?
10. What are the thermal and aiming characteristics?
11. How is DCG affected by DWDM signal conditions?
12. Is grating performance affected at temperature extremes or as a result of temperature cycling?
13. Holographically recorded gratings normally have a spatial efficiency dependence across the grating caused by a laser's Gaussian beam profile. Do your holographic gratings have this spatial dependence?

Q. What type of gratings does Wasatch Photonics manufacture?
A. We make volume phase gratings recorded interferometrically in dichromated gelatin (DCG). There are many other optical recording media. DCG possesses the required combination of characteristics to produce very low polarization dependent loss (PDL) and very high efficiency. These translate into benefits that enable telecom companies to leverage and capitalize on their own technologies.

Q. What information is available on your gelatin recording medium and is it stable over time?
A. Our gelatin recording medium is very similar to the gelatin that has been used in the photography industry for more than 100 years. As you may know, properly processed photographs are very stable and will retain their properties for decades. One of the major reasons for this excellent stability of photographs is the stability of the gelatin base. The discoloration of very old black and white photographs is a result of insufficient removal of fixer from the paper base, which results in a yellowing of the paper. It has nothing to do with the gelatin.

Wasatch Photonics uses a dichromated gelatin (DCG) mixture as its recording medium of choice. Once this mixture is processed and the chromium removed, it is essentially pure gelatin and is very stable. During the past thirty years, there has been no measurable degradation in gelatin gratings that are properly sealed. The DCG holographic scanning disks used in some of the early optical bar code scanners still function exactly as they did over 20

Exhibit A-4

years ago.

Q. What is a Dickson™ grating and why is it different from other gratings?
A. A Dickson™ grating is a highly specialized volume phase transmission grating. It can diffra orthogonal linear polarizations with equal and high efficiency at included angles greater than 90 over 40 nm bandwidths. Other gratings designed to be used at these high diffraction angles wil much greater PDL, lower diffraction efficiency, and a greater variation in diffraction efficiency ac nm bandwidth. The 40 nm bandwidth and favorable high dispersion angles combined with effici near 95% make the Dickson™ grating highly desirable for Telecom applications such as Mux/Demux/Remux, OSA, monitors, filters and Raman Spectroscopy. The grating is named aft grating designer, and Wasatch Photonics Co-Founder, Lee Dickson.

Q. What kind of performance characteristics can be expected from a Dickson™ grating?
A. Dickson™ gratings can easily be designed for any Telecom band from 700 to 1700 nm. For a 940 lpmm Dickson™ grating designed for 1530-1570nm will have these high performance characteristics:

- High Dispersion
- Extremely High Efficiency (>95%)
- Extremely Low PDL (<0.2dB)
- Flat Response Across C, S, or L Bands

Q. Can gratings with different dispersion angles be made?
A. Dickson™ gratings perform in narrow angular ranges, it is this limitation that allows them to v well as they do. There are however two classes of realizable Dickson™ gratings with the first wc a half angle of 47 degrees in air and the other working at internal angles too high to escape fror substrate which must therefore be used with prisms. This latter design is termed the Dickson™ has nearly TWICE the dispersion per pass of a Dickson™ grating.

Q. Over what wavelengths can your gratings operate?
A. We cover the entire visible range and all the way up to 2 microns with a single recording ma your choice of glass substrates and prisms.

Q. What physical sizes can be made?
A. Typical ruggedized sizes with perfect hermetic seals begin at approximately 2 cm x 3 cm. S sizes have to be externally sealed. Gratings as large as 40 cm x 40 cm have been made by the Photonics team.

Q. What wavefront uniformity/distortion can be expected?
A. 1/4 wave is typical. Wavefront uniformity <lambda/40 rms at 633 nm can be achieved for a costs using superior substrates, polishing techniques, etc.

Q. What environmental tests have been performed on your gratings?
A. Our telecom-grade, epoxy sealed gratings have survived boiling water for several days with degradation and 95° C at saturated humidities for more than 2 weeks. A collapse of the grating has been observed after several days at 120° C. Some of our similar, but non-Dickson design, ar currently in comm rcial multiplexers and are surviving real world tests as well as having pa standard compliance testing. Th DCG is hermetically sealed between various substrates suc

Exhibit A-5

Borofloat, low iron sheet glass and fused silica, making it impervious to everything but extreme heat.

Q. What are the thermal and aiming characteristics?
A. Aiming stability over time and temperature is completely dependent upon the substrate used. Near zero drift is obtained by using a substrate with a low thermal coefficient of expansion (TCE) such as fused silica. See these links to Angular Deviation vs. Temperature and Lateral Dispersion (using a 50 mm FL lens vs. Temperature.

Q. How is DCG affected by DWDM signal conditions?
A. There is hardly any absorption in a phase grating. The more common reflection gratings absorb as much as 20% and get really hot. It is not uncommon for communication signals to be between 5 and 50 mw, so adding up a hundred or more channels is a lot of heat. The gratings can take the heat but the losses at the fiber ends will be measured in watts, so heat dissipation probably has to be considered in a device's package. Total absorption and scatter in the grating is about 2 or 3% so it is not a problem. The glue and gelatin begin to soften about 100 watts per square cm continuous wave.

Q. Is grating performance affected at temperature extremes or as a result of temperature cycling?
A. Test results over a temperature range of 0-100° C indicate no significant change in efficiency, <0.5%, for a typical Dickson™ grating. Gratings can also withstand repeated temperature cycling with no measurable degradation in performance.

Q. Holographically recorded gratings normally have a spatial efficiency dependence across the grating caused by a laser's Gaussian beam profile. Do your holographic gratings have this spatial dependence?
A. We have developed novel techniques that significantly reduce variations in diffraction efficiency across our gratings.

Exhibit B Actual Enhanced Volume Phase Grating

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Dated: January 30, 2002

LeRoy D. Dickson

LeRoy D. Dickson, Applicant